PIER Energy-Related Environmental Research
Environmental Impacts of Energy Generation, Distribution and Use

Baseline, Classification, Quantification, and Measurement of Carbon Market Opportunities in California

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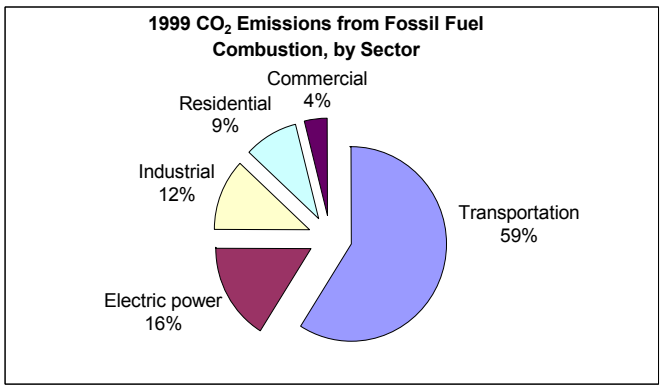
The Issue

Increased atmospheric greenhouse gas (GHG) concentrations contribute to climate change. This phenomenon is sometimes known as *global warming,* because GHGs prevent long-wavelength radiant energy from escaping the Earth's atmosphere, which results in atmospheric warming and an increase in the Earth's temperatures. This temperature rise subsequently affects weather patterns (i.e., climate) and ecosystems.

Worldwide, climate change may produce a variety of effects, from more extreme droughts and floods to a possible increase in the frequency and severity of El Niño events. In California, there is likely to be a shift in the timing, amount, form, and magnitude of precipitation events; a temperature increase; and possibly a sea level rise. These changes could lead to reduced water supplies during the summer and fall, as state snowpacks are exhausted earlier. In fact, spring watershed runoff has already decreased nearly 12% in some California river systems from 1906 to 2001.[1]



This reduction is problematic, because hydropower produces approximately 20% of the electricity that is generated in-state. Moreover, climate change could increase stresses on animals and plants and their habitats—a problem for the hundreds of California's threatened or endangered plant and animal species. Other impacts of climate change could include: extreme winter flooding (if a greater proportion of precipitation is produced as rain instead of

[1] California EPA-California Resources Agency. 2002. *Environmental Protection Indicators for California: Understanding Environmental Conditions through Indicators*.

as snow), more frequent and more intense wildfires, and coastal erosion. These events may not only affect California's citizens, flora, and fauna; they could also damage the state's infrastructure and wreak havoc on its economy.

California's energy sector contributes to climate change by releasing a significant amount of carbon dioxide (CO_2)—a key GHG—into the atmosphere every day. In 1999, California's in-state fossil-fuel power plants produced 16% of the state's total CO_2 emissions.[2] This contribution rises to about 28% if out-of-state power plant emissions serving the state are counted in the state inventory. As a result, power plants (and other large industrial sources) may be targeted in the future for CO_2 emission reductions. At the same time, it is likely that a trading market will be created to allow the emission reductions to occur in the sectors and individual entities with the lowest emission reduction costs.

One particularly promising option for reducing atmospheric carbon is *carbon sequestration*. Atmospheric CO_2 reduction can be accomplished by: (1) preventing plant matter from releasing CO_2 through decomposition, and (2) removing carbon from the atmosphere by increasing the amount of vegetation. Because plants remove carbon from the atmosphere and store it in their tissues, an increase in the abundance of natural vegetation in the state would increase carbon uptake and storage.

California has a variety of options for sequestering carbon, and changes in state land use and management could store significant amounts. The state's vast acreage of managed agricultural and forest lands provide numerous opportunities to sequester carbon through techniques such as restoration of degraded riparian areas, grazing lands, and forest and shrub lands; changes in forest management practices; changes in tillage and cropping practices on agricultural lands; and preservation of old-growth forests. Forestry and land-use change projects are expected to be among the lowest-cost near-term options for reducing GHGs in the atmosphere.

Forestry and agriculture are important economic sectors in California. California agriculture drew in over $25 billion in 2000,[3] and the state's forests, in addition to their ecological and lumber value, contribute to its $75 billion tourist industry.[4] The availability and value of "credits" for storing carbon in soil and vegetation could alter these economic returns and affect future land use. Although extensive data are available on land values and suitability, current land use, and the economic benefits associated with various crops, no systematic assessment of these variables has been made, and few pilot carbon sequestration activities have been implemented in California.

In anticipation of possible CO_2 emissions regulations, most companies in the power sector are already compiling data on current and projected carbon assets and liabilities, and many companies are also sponsoring reforestation projects, in order to learn more about the potential to sequester carbon. The California legislature recently modified the California Climate Action

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[2] California Energy Commission. November 2001. *Inventory of California Greenhouse Gas Emissions and Sinks: 1990–1999.* Figure 7. CO_2 Emissions from Fossil Fuel Combustion by Sector. P600-02-001F.

[3] *The World Almanac and Book of Facts.* 2002. p. 133.

[4] Wilkinson et al. 2002 draft. *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change: California.*

Registry[5] to enable entities to register carbon reductions that are produced by the sequestration of carbon in forested lands or by reforestation. In the future, these emissions reductions may count toward required offsets, or be sold or traded. However, it is still unknown which options are the most successful and cost-effective, or the extent to which each option is available in the state. To ensure that these sequestration projects deliver the carbon reductions sought by regulators, it is essential to quantify the reductions provided by various carbon sequestration strategies.

Project Description

In this project, PIER-EA, EPRI, Winrock International, and the California Department of Forestry worked together to: (1) develop a baseline of carbon emissions and/or sequestration for California's land use and forestry sectors, (2) classify carbon storage opportunities in the state, and (3) design and implement a carbon measurement and monitoring protocol (MMP). This project coordinated efforts with another EPRI/Winrock project measuring carbon storage potential for a range of land-use change and forestry projects, and developing carbon supply curves for important categories of U.S. land use changes and forestry projects.

PIER Program Objectives and Anticipated Benefits for California

This project offers numerous benefits and meets the following PIER program objectives:

- **Providing environmentally sound electricity.** This project provides science-based, peer-reviewed tools, datasets, and methodologies for evaluating and formulating carbon strategies and for designing and implementing practical near-term projects. It increases our understanding of how much carbon can be stored or avoided for various classes of projects in California, and the cost of implementing various strategies. This knowledge should encourage participation among companies and organizations in voluntary carbon reduction programs, and in carbon markets as they emerge in the United States and around the world. Subsequently, more carbon is likely to be sequestered, offsetting the contribution of CO_2 from California's fossil-fuel electricity generators.

  A carbon baseline helps carbon project managers design land-use change and forestry projects by quantifying the impact of different strategies on carbon stocks, and it identifies potential lands available for different classes of projects. It will also help the state to develop guidelines or regulations for landowners seeking to sell carbon credits.

  The classification system will help the state provide information on potential actions to increase total carbon storage and the rate of carbon accumulation in the major carbon pools (e.g., standing biomass, dead wood, soils, root systems, and the understory and forest floor in some land types). California can use the system to help shape state positions on a variety of potential regulatory issues at the local, state, and national level. Supply curves graphically display the cost and availability of a variety of carbon sequestration options.

  Co-benefits of carbon sequestration include: improved fire management, increased income for farmers and ranchers, watershed and riparian restoration, reduced non-point pollution,

[5] This is a non-profit organization created by the state legislature to allow companies to register their annual GHG emissions for potential consideration in any regulatory scheme that may evolve in the future.

habitat protection, biodiversity conservation, reduced emissions of other pollutants, reduced fuel costs for biomass energy systems, and economic gains.

Results

This project consisted of many complex sub-projects; therefore, only the highlights of each study's results are listed here. Please see each project's final report for much more detailed results.

Baseline Greenhouse Gas Emissions for Forest, Range, and Agricultural Lands in California.

This project developed methods for estimating baseline carbon emissions and removals from forests, rangelands, and agriculture lands in California. The analysis revealed that forests and rangelands were responsible for a net removal of CO_2 from the atmosphere of 7.55 million metric tons of CO_2 equivalent per year ($MMTCO_2eq/yr$), and that agricultural lands were responsible for a net emission of 0.35 $MMTCO_2eq/yr$. Non-CO_2 GHG emissions from forest and range lands were estimated to be 0.16 $MMTCO_2eq/yr$, or equivalent to about 2% of the removals by these systems. Nitrous oxide emissions (in CO_2 eq) from agricultural lands are more than 40 times higher than carbon emissions due to land use change. The overall net result would be a removal of 7.20 $MMTCO_2eq/yr$ by forests, 0.18 $MMTCO_2eq/yr$ by rangelands, and an emission of 14.19 $MMTCO_2eq/yr$ by agricultural land.

Measuring and Monitoring Plans for Baseline Development and Estimation of Carbon Benefits for Change in Forest Management in Two Regions: Changing from Even-Age Management with Clearcuts to Uneven-Age Management with Group Selection Harvests.

Researchers assessed the potential carbon benefits from changing harvest management from clearcut to group selection. Each of the site assessments was presented as a specific and independent case study, and each reflects a unique set of conditions. Additional field data was collected. For the Blodgett Forest Research Station, no carbon benefit was found for switching from clearcut to group selection harvests. For the Jackson State Demonstration Forest, over one rotation of the modeled scenarios, even-aged management with group selections yielded increases, from 337 to 645 tons over 23.9 hectares, in total forest carbon storage over clearcuts. This is equivalent to an increase in carbon storage per unit area of 14 to 27 tons C per hectare. The report details the measurements and the types of analyses needed to calculate the carbon stocks for each scenario.

Baseline Development and Estimation of Carbon Benefits for Extending Forested Riparian Buffer Zones in Two Regions: Blodgett Forest Research Station and Jackson State Demonstration Forest.

Researchers carried out a measurement and monitoring activity out to assess the relative biomass carbon storage potential of extending forested buffer zones by 200 feet (100 feet either side of existing regulations) at two study sites representing key California timber production regions. Field data were collected and growth curves were developed for both sites. At Blodgett, extension of riparian buffer zones from 75 feet to 175 feet resulted in carbon storage benefits amounting to ~1,100–1,200 tons over the additional 6.1 hectares of riparian forest retained per straight line kilometer (km) of stream length after 80 years. At Jackson, over one rotation of model scenarios involving different site productivities and initial stand ages, extension of riparian buffer zones from 100 feet to 200 feet either side of the watercourse consistently resulted in an unambiguous increase in carbon storage. Over one rotation, carbon storage

benefits resulting from extension of the buffer area range from 151 to 208 tons of carbon (t C) per hectare—or 921 to 1,269 t C per one kilometer length of stream. Extension of riparian buffer zones by 100 feet in commercially managed forests in California can lead to estimated carbon benefits of 1,100 tons per km of stream over 80 years in mixed Sierran conifer forests and 920 tons per km of stream over 100 years in coastal redwood forests. Additional benefits to California will be in water quality, and in habitat for wildlife and fisheries.

Carbon Supply Curves for Forest, Range, and Agricultural Lands of California.

This project developed carbon supply curves and corresponding maps for the most important classes of carbon sequestration activities in the land-use change and forestry sector. Californian lands were classified into forests, rangelands, and agricultural lands. For forestlands, researchers analyzed estimates of the potential carbon benefits for four alternatives, for 20 year and/or permanent contract periods: (1) allowing timber to age past economic maturity (lengthening rotation time), (2) increasing the riparian buffer zone by an additional 200 feet, (3) changing traditional clearcuts to group selection cuts, and (4) forest fuel reduction to reduce hazard of catastrophic fires, and subsequent use of biomass in power plants. For rangelands, estimates of the potential carbon benefits were analyzed for one alternative—afforestation. And for existing agricultural lands, researchers analyzed only one major activity—conservation tillage. Conclusions include the following:

- No forest management project, regardless of length of project, can provide carbon sequestration at less than $\$2.70/MTCO_2$.
- At a price of \$13.6/ MT CO_2, the total amount of carbon that could be sequestered by afforesting grazing lands and changing forest management over a 20 year period is about 894 MMT CO_2. Thus, total sequestration at \$13.6 per MT could offset about 79% of the state's electricity generating fossil fuel emissions and 28% of the state's transportation emissions.
- The largest potential source of carbon from forest management is lengthening rotation by five years, which could potentially provide 2.16 to 3.91 $MMTCO_2$ at a cost of less than \$13.60/MT CO_2.
- Increasing the riparian buffer zone by 200 feet could sequester 3.91 $MMTCO_2$ permanently (assuming no catastrophic fire risk) at a cost between \$2.7 and \$13.6 per $MTCO_2$.
- Afforestation of rangelands (up to 13.34 million acres potentially available) provides the most carbon at the least cost ($\leq$\$2.7/MT CO_2)—about 33 $MMTCO_2$ at 20 years to 4.57 billion $MTCO_2$ at 80 years.
- Of the possibilities for sequestering carbon on agricultural land in California, conservation tillage seems to offer the greatest potential. Based on a range of carbon sequestration rates of 0.35–0.61 MT/ha/year, it is estimated that California agricultural land could produce up to 3.9 $MMTCO_2$ /year through this means.

Methods for Measuring and Monitoring Forestry Carbon Projects in California.

This project developed guidelines for measuring and monitoring carbon emissions and removals from afforestation, forest management, and forest preservation. Researchers identified various aspects of measurement and monitoring, procedures that should be followed, and calculations that could be used to estimate carbon stocks from forest management activities. The final report presents guidelines for developing a measuring plan, for physically measuring all applicable carbon pools, and for using the results from measurements to obtain estimates of carbon stocks.

Final Reports

The final reports describing the results of this work listed below, and are available at the California Energy Commission website, at the following links:

- *Baseline Greenhouse Gas Emissions for Forest, Range, and Agricultural Lands in California* (500-04-069). www.energy.ca.gov/pier/final_project_reports/500-04-069.html.
- *Measuring and Monitoring Plans for Baseline Development and Estimation of Carbon Benefits for Change in Forest Management in Two Regions: Changing from Even-age Management with Clearcuts to Uneven-age Management with Group Selection Harvests* (500-04-070). www.energy.ca.gov/pier/final_project_reports/500-04-070.html.
- *Baseline Development and Estimation of Carbon Benefits for Extending Forested Riparian Buffer Zones in Two Regions: Blodgett Forest Research Station and Jackson State Demonstration Forest* (CEC-500-2004-071F). www.energy.ca.gov/pier/final_project_reports/500-04-071.html.
- *Carbon Supply Curves for Forest, Range, and Agricultural Lands of California* (CEC-500-2004-068F). www.energy.ca.gov/pier/final_project_reports/500-04-068.html.
- *Methods for Measuring and Monitoring Forestry Carbon Projects in California* (500-04-072F). www.energy.ca.gov/pier/final_project_reports/500-04-072F.html.

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